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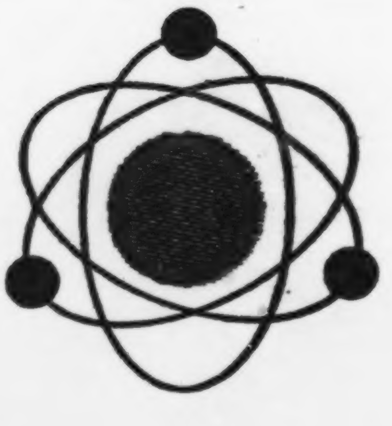
ATOMIC PHYSICS

AN AUTO-INSTRUCTIONAL PROGRAM

David J. Klaus and William A. Deterline

VOLUME 1



AMERICAN INSTITUTE FOR RESEARCH
Pittsburgh, Pennsylvania

AIR-C10-9 61-RP-(1)

ATOMIC PHYSICS

VOLUME 1

David J. Klaus and William A. Deterline

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These materials were prepared for use in an experimental study of the self-tutoring approach in education. Further information concerning the design of the study and the resulting data are contained in reports available from the American Institute for Research.

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Name ____________________

Grade ____________ Age ______

School ____________________

①

INSTRUCTIONS

You will be learning about physics in a new way. These materials are arranged to teach you rapidly and easily if you follow the instructions carefully. As each new principle or fact is explained, you will be given practice using it before you go on to the next principle. This is not a test nor will you be graded on the number of correct answers.

Each step is something like a question. For each item, give the best answer you can. Do not go ahead or skip any question. Each step is important. You are not permitted to go back if you make an error, so try to understand each fact or principle before you go on. Only if it is necessary will you be permitted to go through a unit a second time.

Each step contains one or more blanks that look like this: ☐. Whenever you come to a blank, give the answer you think belongs there. If you read the step carefully, you will find this easy to do. When you have completed the step, you will go on and check your answer with the one given.

Now try this sample item. Read the item carefully. When you have finished, check your answer with the correct answer written below the item.

> Physics is the branch of science that deals with the way non-living things act. The way a gasoline engine operates is an example of what is studied in ☐.

You should have written: physics

Sometimes the word you should use is a simple word, like the word "not" or "only." Try this item.

> Physics does ☐ deal with living animals. Physics is concerned ☐ with non-living things.

You should have written: not - only

This step has three blanks. Read the item carefully and give your answers.

> Some sciences are called exact sciences. Physics is called an ☐ science, but biology is ☐ an ☐ science.

You should have written: exact - not - exact

When you see a blank with a star in it: ☐*, it means that two or more words belong there, and all the words must be given. Try this item.

> Physics is an exact science, but biology is ☐*.

You should have written: not an exact science

③ Sometimes it will be necessary to give an answer in your own words. When you see a blank with two stars, like this: [** ________], finish the sentence in your own words.

> Physics is called an exact science because experiments repeated under the same conditions give exactly the same results. If a physics experiment is repeated, [** ________ ________________].

You should have written: we always get the same results (exactly the same results would be obtained)

Physics uses symbols. A blank like this: [# ____], means that a number should be used; a blank like this: [$ ____], means a symbol, such as a letter or a plus (+) sign belongs there. Words should not be used.

> Degrees of temperature is represented by a little circle, as in 212°. Water freezes at thirty two degrees which we write as [# ____]°. The normal temperature of our bodies is written as 98.6 [$ ____].

You should have written: 32, and °

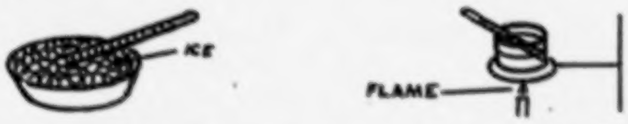
Now try a step which contains several blanks.

> Physics is an [________] science because identical experiments produce exactly the same [________]. For example, you can predict water will boil at [# ____]° and freeze at 32 [$ ____].

You should have written: exact - results - 212 - °

Sometimes a step has a figure with it which will help you get the correct answer; study it carefully before filling in the blank.

In this experiment, you can predict that the thermometer on the ________, will have the lower reading.



You should have written: left

You have practiced all the kinds of steps.

Remember:

1. This is not a test; it is a way to learn.
2. Try each step, even if you have to guess.
3. Read each step through carefully before you give an answer.
4. Try to use the words a physicist would use.

⑤

DIRECTIONS FOR USING THIS BOOK

The pages of this book have been arranged in a special way. Here is how to follow along and do the steps in the right order.

As you start each unit, the steps will be along the top row of the pages. You should read step 1, write your answer, and then turn the page to see the correct answer on the following page. The answer to step 1 will also be at the top on the right-hand page. To see step 2, you should again turn the page, always looking at the top of the next right-hand page. You always have to turn to the next page to find the answer to a question, and then turn the page again to go on to the next question.

Each unit begins and ends with a yellow page. When you get to the last page of the unit, you will see directions telling you how to turn the book around and go on with the next step.

Altogether, there are five rows of steps on each page. You should only pay attention to the steps in the row you are working on.

Once you get started, you will find it easy to follow along properly. Just be sure you do the steps in their proper order. Each step has been numbered to help you. The question for each step is numbered with a capital letter (like A-27) and the answer for that step is numbered with a small letter (like a-27).

Remember, after answering each question, turn the page to see the answer, and then turn the page again to see the next step.

Do not try to do too much at one time. You will make fewer errors and remember more of what you have learned if you stop and relax every once in a while.

⑦

UNIT A - The Atom

⑧

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER A-13

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER A-25

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER A-37

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER A-49

END OF UNIT

← START HERE

A-1 All substances are made up of atoms. Salt, for example is made up of ☐.

⑨

A-13 Atomic physics deals with substances consisting of only one kind of atom, that is, with ☐. There are only ☐ elements found in nature.

A-25 Hydrogen is the lightest atom; it has only one ☐ in its nucleus.

A-37 In addition to protons, the nucleus of every atom except hydrogen contains another kind of particle called the neutron (new-tron). Most nuclei contain both protons and ☐.

A-49 A neutral atom always has ☐ ☐.

a-12

not

01

a-24

proton
protons

a-36

nuclei

a-48

protons (electrons)
electrons (protons)

⑪

a-1

atoms

a-13

elements

92

a-25

proton

a-37

neutrons

a-49

as many protons as it has electrons (an equal number of positive and negative charges)

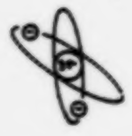
A-12 Because water is composed of two kinds of atoms it is ☐ an element; it is a compound.

⑫

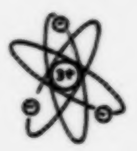
A-24 Within the nucleus there are particles called protons. The nucleus of a hydrogen atom contains only one ☐. The nucleus of a uranium atom contains many ☐.

A-36 The plural of nucleus is nuclei (new-klee-eye). All atomic ☐ contain protons.

A-48 An atom with more protons (+) than electrons (–) has a positive charge. An atom is neutral only when it has exactly as many ☐ as it has ☐.



POSITIVELY CHARGED ATOM



NEUTRAL ATOM

A-2 Not only are solid substances like salt made up of ________, but liquid substances like water or a gas like hydrogen are also ________________.

⑬

A-14 A substance consisting of more than one kind of atom is not an ________. A compound, such as glass, is not an element because it consists of ______________________ ________.

A-26 Hydrogen has an atomic number of one, which is the same as the number of ______________ in its nucleus.

A-38 The hydrogen nucleus contains one proton but no neutrons. The helium nucleus, atomic number 2, has two ________ and, in addition, has two ________.

A-50 An atom that is not neutral is called an ion (eye-on). When an atom has unequal numbers of positive and negative charges it is called an ______.

a-11

same kind

⑭

a-23

electrons around a nucleus (a nucleus with electrons in orbits around the nucleus)

a-35

one proton

92 protons in its nucleus

a-47

neutral

a-2

atoms
made up of atoms

⑮

a-14

element
more than one kind of atom

a-26

protons

a-38

protons
neutrons

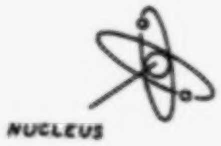
a-50

ion

A-11 Even a small amount of an element contains vast numbers of atoms, but they all are the ____ of atoms.

91

A-23 The structure of every atom is basically the same; it consists of ____ ____.



A-35 Hydrogen has only ____ in its nucleus. Uranium has ____.

A-47 When an atom has an equal number of positive and negative charges it is called a neutral atom. An atom with an equal number of protons and electrons is a ____ atom.

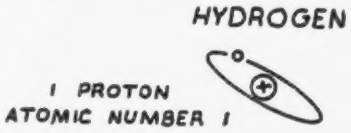
END OF UNIT

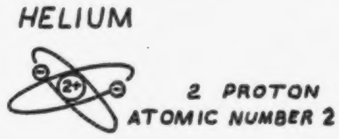
A-3 Atoms are not all alike, that is, there are different kinds of atoms. Different substances are made of ☐ kinds of atoms.

⑰

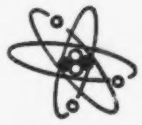
A-15 Elements are assigned numbers called atomic numbers according to their weight. The lightest element has an ☐ number of 1, the heaviest has an ☐ of ☐.

A-27 The atomic number of each element indicates the number of ☐ in the nucleus. A heavier atom has more protons than a lighter atom and has a higher ☐.





A-39 Atomic nuclei contain 2 kinds of particles, ☐ and ☐. A third kind of particle, the ☐, orbits around the nucleus.



A-51 An atom is neutral when it has as many electrons as protons. An ion is ☐ neutral, since it does not have the ☐ number of protons as electrons.

a-10

elements

one kind of atom

(81)

---

a-22

electrons

orbits around the nucleus

---

a-34

protons

atomic

protons

---

a-46

equal (the same)

negative

---

a-58

protons than electrons (positive charges than negative charges)

a-3

different

a-15

atomic
atomic number
92

a-27

protons
atomic number

a-39

protons (neutrons)
neutrons (protons)
electron

a-51

not
same

A-10 Only 92 ☐ occur in nature. Copper is an element because copper is made up of only ☐ ☐.

A-22 Every atom has a nucleus and has ☐ that move in ☐ ☐.

A-34 The nucleus of every atom contains particles called ☐. The ☐ number of an element is the same as the number of ☐ contained in its nucleus.

A-46 When an atom has as many electrons as it has protons, it has an ☐ number of positive and ☐ charges.

A-58 Atomic physics deals mainly with positive ions, those having more ☐. In a laboratory, it is easier to remove electrons from an atom than to add them.

A-4 Copper and iron are both made up of ☐, but they are made up of different ☐ of atoms.

㉑

A-16 Hydrogen is the lightest element, its ☐ is I. Uranium is the heaviest ☐; its atomic number is ☐.

A-28 An element, such as iron, consists of only one ☐ of atom. Every atom of the same element has the same number of ☐ in the nucleus.

A-40 Particles can be electrically charged or they can be electrically neutral. A particle without an electrical charge is electrically ☐.

A-52 When the number of electrons in an atom is not equal to the number of protons, the atom is not ☐ An atom that is not neutral is called an ☐

a-9

92
atom

㉒

---

a-21

electrons
orbits
nucleus

---

a-33

atomic number
atomic numbers
heavier

---

a-45

do not
neutral
neutral

---

a-57

electrons
protons
negative ion (you should say ion, but negatively charged atom would also be correct)

a-4

atoms
kinds

---

a-16

atomic number
element
92

---

a-28

kind
protons

---

a-40

neutral

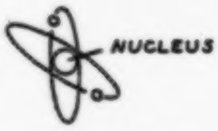
---

a-52

neutral
ion

A-9 There are only 92 elements that occur in nature. Each of these ____ elements consists of only one kind of ________.

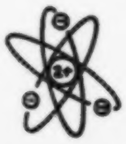
A-21 An atom consists of a nucleus and one or more electrons. The ____________ move in ____________ around the ____________.



A-33 Every element has a number called an ________________ ________. Lighter elements have smaller ________________ than ____________ elements.

A-45 Neutrons ________ have an electrical charge; they are ____________ particles. Protons and electrons are not ____________. they are electrically charged.

A-57 This atom has more negatively charged ____________ than positively charged ____________; it is a ____________________.



A-5 Salt, water and hydrogen are different substances; they are made up of ☐ of atoms.

㉕

A-17 Elements are defined as those substances which ☐ ☐.

A-29 The number of protons in the nucleus of an atom is indicated by the ☐ of that element.

A-41 A neutron has no electrical charge. As its name suggests, it is electrically ☐.

A-53 An atom with excess electrons has a ☐ charge and thus it is called a negative ☐. An atom with too few electrons is called a ☐.

a-8

element

a-20

orbits (paths)
nucleus

a-32

element
nucleus
electrons

a-44

charged
negatively charged particles

a-56

atom
electrons

a-5

different kinds

---

a-17

consist of (are made up of) only one kind of atom

---

a-29

atomic number

---

a-41

neutral

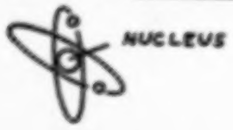
---

a-53

negative
ion
positive ion

A-8 A substance which consists of only one kind of atom is called an element. Any substance consisting of more than one kind of atom is not an ________.

A-20 In our solar system, the planets move in paths, called orbits, around the sun. In an atom there are small particles called electrons which move in ________ around the ________.



A-32 All substances consist of atoms. A substance consisting of only one kind of atom is called an ________. Every atom consists of a ________ at its center with ________ in orbit around it.

A-44 Protons are positively ________ particles. Electrons are ________.

A-56 An ion is an ________ that is not neutral; it has either too few or too many ________ compared to its number of protons.

A-6 All substances are made up of ☐, but different substances are made up of ☐.

㉙

A-18 Only ☐ different elements are found in nature. Each element has an ☐ which is assigned by weight.

A-30 Hydrogen has one proton; helium has two protons; thus, the element which has an atomic number of 1 is ☐, and the element which has an atomic number of 2 is ☐.

A-42 A neutron is electrically neutral, but protons and electrons are both electrically charged. Protons have a positive (+) charge. Electrons, on the other hand, have a ☐ (–) charge.

A-54 An atom that has too many or too few electrons is called an ☐. An atom with excess electrons is a ☐ charged ☐.

a-7

more

atom

a-19

nucleus

a-31

2

92 protons in its nucleus

a-43

negative

positive

a-55

positively or negatively charged atom

a-6

atoms

different kinds of atoms

(31)

---

a-18

92

atomic number

---

a-30

hydrogen

helium

---

a-42

negative

---

a-54

ion

negatively

ion

A-7 Some substances such as carbon consist of only one kind of atom; while other substances, such as chalk, consist of ☐ than one kind of ☐.

A-19 Physicists sometimes describe atoms as looking like our solar system. The center of an atom is called the nucleus (new-klee-us). Just as the center of the solar system is the sun, the center of an atom is the ☐.

A-31 Helium has two protons in its nucleus; its atomic number is ☐. Since uranium has an atomic number of 92, we know that uranium has ☐.

A-43 An electron has a ☐ (–) electrical charge, while a proton has a ☐ (+) electrical charge.

A-55 In chemistry, an ion is a positively or negatively charged atom. In atomic physics, an ion is also a ☐.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER A-7

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER A-19

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER A-31

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER A-43

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER A-55

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UNIT B - Atomic Particles

Plus review of Unit A

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER B-3

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER B-17

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER B-31

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER B-45

END OF UNIT

START HERE

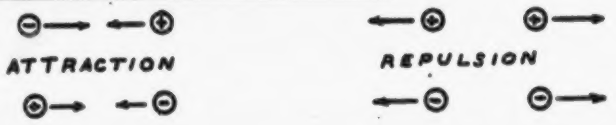
rA-1 All substances are made up of ________. A substance consisting of only one ________ of atom is called an element.

㊲

B-3 A neutral atom has an equal number of positive and negative charges. This means that there are as many ________ in orbit as there are ________ in the nucleus.

B-17 Protons and electrons have opposite charges, but the size of charge on an electron is exactly ________ to the size of charge on a proton.

B-31 The general rule of attraction or repulsion is that like charges ________ each other, and ** ________ ________.



B-45 The ________ at the center of most atoms contains both * ________.

b-2

electrons
negatively

b-16

smallest positive charge possible

b-30

repel
attract

b-44

elements
elements
kind of atom

ra-1

atoms
kind

(39)

---

b-3

electrons
protons (positive charges)

---

b-17

equal (the same)

---

b-31

repel
unlike charges attract each other

---

b-45

nucleus
protons and neutrons

㊵

B-2 Orbiting about the nucleus of an atom are __________ which are __________ charged.

HYDROGEN ATOM

HELIUM ATOM

B-16 The charge on atomic particles is very small. The charge on an electron is the smallest negative charge possible and the charge on a proton is the ______________________________.

B-30 Like charges repel each other. Electrons will __________ electrons. Opposites attract. Electrons will __________ protons.

B-44 There are 92 __________ that occur in nature. Each of the 92 __________ consists of only one __________ __________.

rA-2 There are only 92 __________ that occur in nature. Each element is identified by a number called an __________ __________.

㊶

B-4 Hydrogen has an atomic number of 1. This means that the hydrogen nucleus contains one __________. A neutral hydrogen atom has __________ in orbit.

B-18 There are equal numbers of protons and electrons in a __________ atom.

B-32 Electrons are negatively charged. Thus, two electrons will __________ [illegible] __________ __________.

B-46 The __________ of an atom always indicates the number of __________ in the nucleus.

b-1

protons (particles)
positive
nucleus

b-15

charged
charged
neutral
never neutral (always positively charged)

b-29

opposites
attract

b-43

the centrifugal force and the force of attraction are equal
(the two forces on the electron are equal)

ra-2

elements
atomic number

㊸

---

b-4

proton
one electron

---

b-18

neutral

---

b-32

repel
like charges

---

b-46

atomic number
protons

B-1 In an atom, all the positively charged ______ are in the nucleus; thus, the nucleus itself has a ______ charge. The ______ of every atom has a positive charge.

㊹

B-15 An atom may be positively ______, negatively ______, or ______. A nucleus, however, is ** ______.

B-29 You can remember the rule of attraction and repulsion if you remember that "opposites attract." Positive and negative charges are ______ and they ______ each other.

B-43 An electron stays in orbit in its atom because ** ______ ______ ______.

rA-3 An element is a substance which consists of ______ ______.

㊺

B-5 The atomic number of helium is 2. A neutral helium atom has ___ protons in the nucleus and ___ electrons in orbit.

B-19 The positive and negative charges in a neutral atom exactly cancel each other because they are opposite and because they are ______ in size.

B-33 An electron and a positive ion will ______ each other because they have ______.

B-47 An electron has the smallest ______ charge possible and a proton has the ______ ______. These charges are opposite but ______ in size.

ra-12

it has equal numbers of electrons and protons (positive and negative charges)

---

b-14

positive charge
never

---

b-23

repel

---

b-42

equal
away from the nucleus

---

ra-3

only one kind of atom

b-5

2

2

b-19

equal (the same)

b-33

attract

unlike charges

b-47

negative

smallest positive charge possible

equal (the same)

rA-12 An atom is neutral when ____.

B-14 Since all the positive charges in an atom are in the nucleus, the nucleus always has a ________________. The nucleus of an atom is ________ neutral.

B-28 Two electrons repel each other, and two positively charged ions repel each other. Two unlike charges attract each other; but two like charges ________ each other.

B-42 An electron stays in orbit because the two forces acting on it are ________. One force, centrifugal force, pulls the electron ________________________.

㊾

rA-4 The structure of an atom is like the ______ of our solar system. An atom consists of a central part called a ______, surrounded by ______ in orbit.

SUN
PLANETS

B-6 The atomic number of an atom indicates the number of ______ in the nucleus. In a neutral atom, the number of ______ is the same as the number of protons.

B-20 Protons are always ______ charged and electrons are always ______. The size of their charges is always ______ to each other.

B-34 As you have already learned, electrons in an atom move in ______ around the ______ at the center.

B-48 A neutral atom is one which has ______ ______.

ra-11

6 protons
neutral atom

㊿

---

b-13

positively

---

b-27

negative
attract

---

b-41

pull the electron toward the nucleus

---

ra-4

structure
nucleus
electrons

(51)

b-6

protons
electrons

b-20

positively
negatively charged
equal (the same)

b-34

orbits (paths)
nucleus

b-48

an equal number of protons and electrons (the same number of positive and negative charges)

rA-11 The atomic number of carbon is 6; this means that the nuclei of all carbon atoms contain ☐*. If a carbon atom has 6 electrons in orbit, it is a ☐*.

㉕

B-13 An atom may not have an equal number of protons and electrons. If it has too few electrons, the atom is ☐ charged.

B-27 A positive ion will attract electrons. In the same way, electrons, which have a ☐ charge, will attract positive ions. This is true of all unlike electrical charges; they ☐ each other.

B-41 The force of attraction acting on an electron in orbit tends to ☐**.

---

rA-5 All atoms have basically the same structure. An atom has both a central ______ ______.

(53)

B-7 A neutral atom has an equal number of ______ and ______. The atomic number tells how many ______ and ______ the neutral atom contains.

B-21 Neutrons have ______ electrical charge. Both neutrons and protons are found in the ______ of all atoms except hydrogen.

B-35 The force of attraction between ______ electrical charges is important in understanding why the ______ stay in their orbits.

B-49 In a neutral atom, the atomic number indicates both the number of protons in the nucleus and ______ ______.

(54)

ra-10

neutral atom
positively
ion

---

b-12

nucleus
all

---

b-26

loses
ion

---

b-40

pull the electron away from the nucleus

---

ra-5

nucleus and electrons in orbit around the nucleus

---

b-7

protons (electrons)
electrons (protons)
protons (electrons)
electrons (protons)

---

b-21

no (neutral)
nuclei

---

b-35

unlike
electrons

---

b-49

the number of electrons (in orbit)

rA-10 All atoms of oxygen have eight protons, so an oxygen atom with only six electrons is not a *______. It is a ______ charged ______.

(56)

B-12 Every atom has a central portion called a ______. The nucleus contains ______ of the positive charges in an atom.

B-26 When an atom loses an electron, it ______ one negative charge and is called a positive ______.

B-40 The centrifugal force acting on an electron in orbit tends to **______.

END OF UNIT

rA-6 The nucleus of an atom consists of two kinds of particles; ☐ which are positively charged, and ☐ which are electrically ☐.

㊼

B-8 The number of protons in a nucleus is indicated by the ☐ of the element.

B-22 A nucleus with one proton has a single positive charge or, as physicists say, a charge of +1. A nucleus with four protons has a charge of +☐. A nucleus with ten protons has a charge of ☐.

B-36 If you tie an object at the end of a string and whirl it around, there is a force pulling the object ☐ from you. This is called "centrifugal" force (sen-trif-you-gil).

B-50 An atom that is not neutral is called an ☐. An atom that has lost electrons is called a ☐.

ra-9

negatively
(positively charged) protons
ion

---

b-11

the same number of protons in its nucleus as it has electrons in orbit (as many positive charges as it has negative charges)

---

b-25

protons
neutral
positively

---

b-39

equal

---

b-53

away from the nucleus
attraction
in its orbit

ra-6

protons
neutrons
neutral

---

b-8

atomic number

---

b-22

4
+10

---

b-36

away

---

b-50

ion
positive ion

rA-9 An atom is neutral when it has exactly as many ______ charged electrons as it has ______ ______. An atom which is not neutral is called an ______.

09

B-11 A neutral atom has exactly ______ ______.

B-25 If a neutral atom "loses" an electron, it then has more ______ than electrons. It is no longer a ______ atom, but instead it is a ______ charged ion.

B-39 An electron will remain in orbit if the strength of the centrifugal force and the force of attraction are ______.

B-53 Although centrifugal force tends to pull an electron ______, the force of ______ between the negative electron and the positive nucleus holds the electron ______.

rA-7 An electron has a ☐ electrical charge, a proton has a ☐, and a neutron ☐.

(61)

B-9 A neutral atom has an ☐ number of protons and electrons. Thus, in a neutral atom, the number of ☐ as well as the number of protons is indicated by the ☐ ☐.

B-23 An atom can have an electric charge if it has unequal numbers of ☐ and ☐.

B-37 Centrifugal force tends to pull a revolving electron away from the ☐ in the center of the atom.

B-51 A positive ion will repel other ☐, and will ☐ electrons

ra-8

nucleus
atomic number
protons

---

b-10

protons
negatively

---

b-24

+3
−4

---

b-38

away from
unlike (opposite)
toward the nucleus

---

b-52

repel
unlike charges attract

ra-7

negative

positive charge

has no charge (is neutral)

---

b-9

equal

electrons

atomic number

---

b-23

protons (electrons)

electrons (protons)

---

b-37

nucleus

---

b-51

positive ions (positively charged particles)

attract

rA-8 The number of protons in the ________ of an atom is indicated by the ________ of the element. The nuclei of all atoms of the same element have exactly the same number of ________.

B-10 In a neutral atom, the positively charged ________ are exactly balanced by the ________ charged electrons.

B-24 An atom with three protons and five electrons has a charge of −2. An atom with seven protons and four electrons has a charge of ____. One with four protons and eight electrons has a charge of ____.

B-38 In an atom, centrifugal force tends to pull an electron ________ the nucleus, while the force of attraction between ________ charges tends to pull the electron ________ ________.

B-52 In general, like charges ________, and ________ ________.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rA-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER B-10

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER B-24

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER B-38

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER B-52

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UNIT C - Cathode Rays

Plus review of Unit B

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER C-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER C-24

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER C-40

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER C-56

END OF UNIT

← START HERE

rB-1 All of the __________ charged protons in an atom are in the nucleus; thus the __________ itself has a __________.

(69)

C-8 The negative terminal of a battery, or other source of electrical energy, is called the cathode (kath-ode). The negative wire in the tube is also called a __________.

C-24 Velocity means speed. Only objects which are moving have __________. An object which is not __________ has no speed, that is, it has zero __________.

C-40 The greater the __________ of attraction between two objects, the __________ the reading on a scale placed between them.

C-56 The first things discovered about cathode rays were that they move in __________ and that they are particles having both __________ and __________.

c-7

negative

70

---

c-23

mass

velocity

---

c-39

force of attraction

mass

---

c-55

amount of matter

speed

rb-1

positively
nucleus
positive charge

---

c-8

cathode

---

c-24

velocity
moving
velocity

---

c-40

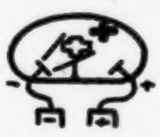
force
greater

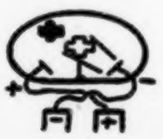
---

c-56

straight lines
mass
velocity

C-7 By experimenting, it was found that the shadow was always on the wall of the tube opposite to the negative wire. Hence, the rays came from the ________ wire.





72

C-23 The particles coming from the negative terminal in a cathode ray tube have both ________ and ________.

C-39 If we put a scale between an apple and the Earth, we can measure the ________ between them. The reading on the scale depends upon the ________ of each of the objects.

C-55 To review, cathode ray particles have both mass and velocity. Mass means the ________ in an object. Velocity means the ________ with which an object is moving.

rB-2 Helium's atomic number is 2, which means its nucleus has ______ positively charged ______, and that a neutral helium atom has ______ in orbit.

(73)

C-9 The rays that were observed were named cathode rays since they came from the negative wire, which is called a ______.

C-25 When an object has velocity, it means that it ______ ______.

C-41 Since the force of attraction between two nearby objects depends on their mass, the greater the ______ of the objects, the ______ between them.

C-57 Cathode rays are not like light rays. They actually are small ______ of ______.

c-6

shadow

line (path)

---

c-22

mass

velocity

---

c-38

force of attraction

masses

---

c-54

force

move it (stop it from moving)

---

rb-2

2
protons (particles)
two electrons

---

c-9

cathode

---

c-25

is moving (has speed)

---

c-41

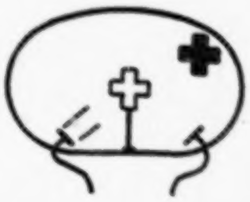
mass
greater (larger) the force of attraction (the attraction)

---

c-57

particles
matter

C-6 When the wires were connected to a source of electrical energy, there was a ☐ on the wall of the tube. This meant that the rays, like light rays, travel in a straight ☐.



C-22 To exert a force, objects must have both mass and velocity. Since the pinwheel moved, the particles striking them exerted a force, thus they must have both ☐ and ☐.

C-38 Objects have mass, and thus attract each other. The ☐ between any two objects depends on their ☐.

C-54 Weighing is one method of measuring mass. Another means of measuring mass is measuring the amount of ☐ required to ☐.

---

rB-3 A neutral atom has ________________________ ________________.

(77)

C-10 The vacuum tubes that were used were called cathode ray tubes since they were used to study ________________.

C-26 The particles also have mass. Mass means the amount of matter in a substance. The greater the amount of matter in an object, the greater is its ______.

C-42 The moon has less mass than the Earth. Thus, a scale would show that the force of attraction between an apple and the moon is ______ than the attraction between an apple and the Earth.

C-58 The cathode ray particles were named electrons. At that time little was known about the atom, but physicists had learned about ______________ from their studies using __________ __________ tubes.

c-5

shadow

c-21

showing that they could exert a **force** (on a pinwheel cathode ray tube)

c-37

force of attraction

c-53

move

stop

rb-3

equal numbers of protons and electrons (equal numbers of positive and negative charges)

c-10

cathode rays

c-26

mass

c-42

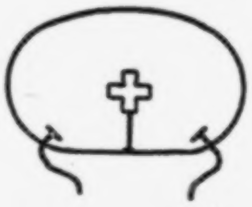
less

c-58

electrons

cathode ray

C-5 To find out why the tube glowed, some tubes were built with an object in them. If the glow was produced by rays resembling light rays, the object would cast a ________ on the wall of the tube.



C-21 One way in which it was possible to demonstrate that cathode rays consisted of small particles was by ** ________ ________.

C-37 Because the Earth and an apple both have mass, they will attract each other; there will be a * ________ between them.

C-53 The greater the mass of an object, the greater would be the force required to ________ it or to ________ it from moving.

rB-4 An ion is an atom that is not ________. An atom with too few electrons is a ________.

(81)

C-11 The special glass tubes used in experiments with cathode rays were called ________.

C-27 Mass means amount of matter. A baseball has mass which means it consists of an ________ of ________.

C-43 When we weigh an object, we measure the ________ ________ between the object and the Earth. The greater the mass of the object, the more it ________ on the Earth.

C-59 Cathode rays consist of a stream of very small particles called ________. These ________ have both mass and velocity.

c-4

glow

---

c-20

move

exerted a force

---

c-36

large (great)

smaller (less)

---

c-52

weighing

force

---

rb-4

neutral
positive ion

c-11

cathode ray tubes

c-27

amount
matter

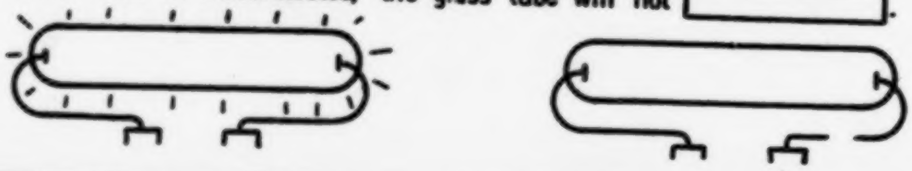
c-43

force of attraction
weighs

c-59

electrons
electrons (particles)

C-4 When wires in the ends of a glass vacuum tube are connected to a source of electrical current, the tube will glow. If either wire is disconnected, the glass tube will not ☐.



C-20 When the wires were connected, the pinwheel did ☐. This meant cathode rays consisted of matter because they ☐ on the pinwheel.

C-36 When an apple falls, only the apple moves very much because the mass of the earth is very ☐ while the mass of the apple is much ☐.

C-52 An object requires force to move it or to stop it. The mass of an object can be measured not only by ☐ it, but also by measuring the amount of ☐ required to move the object.

rB-5 An electron has a ________ charge and a proton has a ________. Because they have unlike charges, an electron and a proton will tend to ________ each other.

85

C-12 Experiments showed that the rays came from the negative wire, called the ________, and that a shadow could be produced, indicating the rays traveled in a ________ line.

C-28 Cathode ray particles have mass even though they consist of only a small ________ of ________.

C-44 A bowling ball has more mass than a baseball. The bowling ball would weigh more on a scale resting on Earth because its mass was ________.

C-60 From their experiments, physicists knew that the glow in their glass tubes was due to a stream of ________ coming from the cathode, which is the ________ wire in the tube.

c-3

air

c-19

(small) particles of matter

c-35

Earth is being attracted by the apple

c-51

weight means how much it is attracted to another object
(there is no other object nearby)

rb-5

negative
positive charge
attract

c-12

cathode
straight

c-28

amount
matter

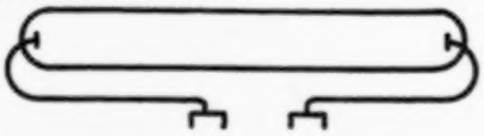
c-44

greater

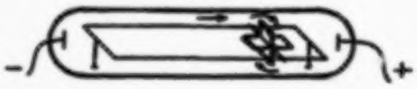
c-60

electrons
negative

C-3 One series of experiments dealt with electrical activity in glass vacuum tubes. A vacuum tube is one from which almost all the ________ has been removed.



C-19 When the wires of the tube were connected to a source of electricity, the pinwheel did move. Since the cathode rays exerted a force, this meant they consist of * ________ ________.



C-35 When we see an apple fall, the apple is being attracted by the Earth; and furthermore, since two objects with mass attract each other, the ** ________ ________ as well.

C-51 An object in space has mass but it does not have weight because ** ________ ________.

rB-6 The general rule is that like charges ☐ each other and that ☐ ☐.

C-13 Next, it was important to find out if ☐ rays closely resembled light rays or if they were made up of small particles of matter.

C-29 Mass means the ☐ in an object.

C-45 On the moon, an object would weigh ☐ than it does on the Earth.

C-61 Because an object placed in the path of electrons in a cathode ray tube cast a ☐, physicists knew that the electrons traveled in ☐.

c-2

electrical

06

---

c-18

force

particles of matter

---

c-34

attract

---

c-50

amount of matter

measuring

---

rb-6

repel

unlike charges attract each other

---

c-13

cathode

---

c-29

amount of matter

---

c-45

less

---

c-61

shadow

straight lines

C-2 The particles that make up atoms were discovered and measured in experiments on electricity. Within atoms there are particles which have positive and negative ______ charges.

㉖

C-18 Cathode rays would not cause the pinwheel to move unless they exerted a ______. If the pinwheel moved, this would indicate the rays consisted of ______.

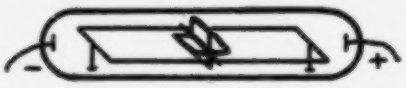
C-34 The Earth and an apple both have mass; therefore, they will ______ each other.

C-50 Mass is not the same thing as weight. Mass means the ______ in an object, and weight is only one means of ______ mass.

rB-7 The charge on atomic particles is very small. Electrons have the smallest __________ charge possible and protons have the __________________________ __________.

(93)

C-14 A tube was built with a pinwheel resting on tracks. If light rays were focused on the pinwheel, they would exert no force, and the pinwheel would ______ move.



C-30 The Earth consists of more matter than a baseball, therefore the mass of the Earth is __________ than that of a baseball. The greater the mass of an object, the greater is the __________ __________ in it.

C-46 An object would weigh less on the moon because the moon has less ________ than the Earth and hence the ________ __________________ between the object and the moon would be smaller.

C-62 Because electrons could cause a pinwheel placed inside a __________________ tube to move, they knew electrons had both ________ and __________.

c-1

positive
negative
no (a neutral)

94

c-17

would not
particles
would

c-33

mass (masses)
the greater the force (strength) of attraction

c-49

matter
another object (the Earth)

rb-7

negative

smallest positive charge possible

---

c-14

not

---

c-30

greater

amount of matter

---

c-46

mass

force of attraction

---

c-62

cathode ray

mass

velocity

C-1 Atoms are composed of protons, electrons, and neutrons. Protons have a [ ] electrical charge and electrons a [ ] charge, but neutrons have [ ] charge.

C-17 If cathode rays were like light rays, they [*] move the pinwheel, but if they were made of small [ ] of matter, they [ ] move the pinwheel.

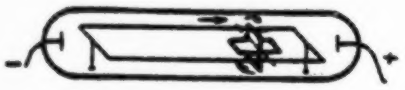
C-33 The force of attraction between objects depends upon their masses -- the greater the [ ] of each of the two objects, [**] between them.

C-49 Mass is the amount of [ ] in an object. Weight means how much the object is attracted to [*].

---

rB-8 The charges on electrons and protons are ______ to each other but they are ______ in size.

C-15 If the rays were made up of small particles of matter, the stream of cathode rays would exert a force on the pinwheel, and it would ______.



C-31 Mass does not mean size or volume; a balloon the same size as the Earth would not have the same ______ as the Earth.

C-47 Weight is a measure of the attraction between two objects and depends on their ______. Thus, an object by itself in space has mass but it has no ______.

C-63 Experiments with the special tubes showed that electrons came from the negative terminal or ______, that they traveled in ______, and that they had both ______.

rb-9

away from
attraction
equai (the same)

---

c-16

matter
force
move

---

c-32

other
force

---

c-48

weight
mass

---

rb-8

opposite
equal

---

c-15

move

---

c-31

mass

---

c-47

mass
weight

---

c-63

cathode
straight lines
mass and velocity

rB-9 Electrons are held in orbit because centrifugal force, which tends to pull the electron ☐ the nucleus, and the force of ☐ pulling electrons toward the nucleus are ☐ in strength.

(001)

C-16 If cathode rays were like light rays, they would not exert a force on the pinwheel, but if they consisted of particles of ☐, they would exert a ☐, and the pinwheel would ☐

C-32 Two bodies that have mass attract each ☐: there is a force of attraction between them. This ☐ of attraction depends on their masses.

C-48 An object in space has no ☐, but it does have ☐ because it consists of a certain amount of matter.

END OF UNIT

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rB-9

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER C-16

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER C-32

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER C-48

END OF UNIT

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(103)

UNIT D - Measuring the Electron

plus review of Unit C

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER D-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER D-22

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER D-36

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER D-50

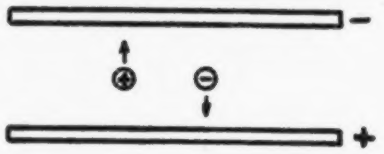
END OF UNIT

START HERE

(105)

rC-I Atoms consist of three kinds of particles; negatively charged electrons, [ ] charged protons, and neutrons, which are electrically [ ].

D-8 A positively charged plate will repel positively charged particles and attract [ ].



D-22 A charged particle moving through an electric field will be deflected. A magnetic field also [ ] charged particles.

D-36 By adjusting the strength of the two fields, it was possible for Thomson to control the path of the beam of [ ], and cause the team to strike the [ ] wherever he wanted.

D-50 The term e/m means the [ ] of the charge on an electron to its [ ].

d-7

not exert a force

d-21

magnetic field

force

d-35

opposite (both)

d-49

e/m

rc-1

positively
neutral

107

---

d-8

negatively charged particles

---

d-22

deflects

---

d-36

electrons
fluorescent screen

---

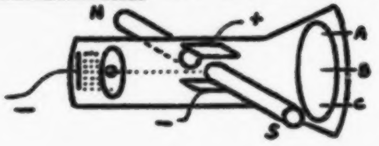
d-50

ratio
mass

D-7 Charged metal plates only exert a force on charged particles passing between them. The plates will ______________ ______________ on uncharged particles passing between them.

D-21 The area between two magnetic poles is a ______________ ______________. If a charged particle passes through this field, a ______________ will be exerted on the particle.

D-35 If both the electric and magnetic fields in Thomson's tube were on at the same time, the forces acting on the electron beam would be in ______________ directions, one up and one down.



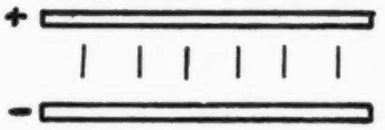
D-49 Physicists use the symbol "e" to mean charge, and "m" to mean mass of the electron. In symbols, they would write the ratio charge/mass as \$______.

---

rC-2 A cathode ray consists of a beam of negatively charged ☐ which were found to stream from the negative terminal, or ☐, of a specially designed vacuum tube.

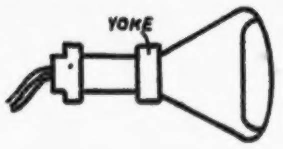
109

D-9 The pattern of force between two magnets is called a magnetic field. There is also a pattern of force between two charged metal plates which is called an electric ☐.



D-23 The location of the magnet's North poles, the path of the particle and the charge of the particle all affect the direction in which a charged particle will be ☐ by a ☐ ☐.

D-37 A television picture tube resembles Thomson's tube. In a TV tube, the beam of electrons that streams from the negative terminal, or ☐, is controlled by a set of electromagnets called the "yoke."



D-51 Thomson found that the ratio, e/m, which is the relationship between the ☐ on an electron and its ☐ was always ☐.

d-6

charge

011

---

d-20

field

---

d-34

deflected

A

C

---

d-48

velocity

deflection

---

rc-2

electrons (particles)
cathode

(111)

---

d-9

field

---

d-23

deflected
magnetic field

---

d-37

cathode

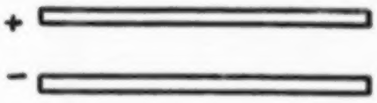
---

d-51

charge
mass
the same (constant)

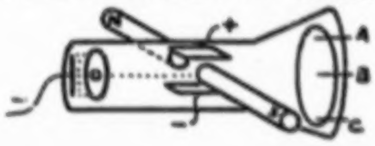
D-6 A force will be exerted on charged particles passing between two charged plates. The direction of the force, up or down, will depend on the ☐ on the particle.

(211)



D-20 Just as the area between two charged plates is an electric field, the area between two magnetic poles is a magnetic ☐.

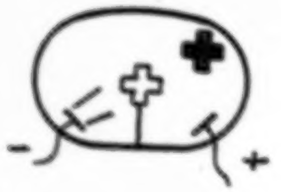
D-34 When Thomson turned on only the electric field, the beam of electrons was ☐ toward point ☐ $. If only the magnetic field was on, the electrons struck the fluorescent screen near point ☐ $.



D-48 Thomson was able to study the charge to mass ratio of electrons by measuring their speed or ☐ and the amount of ☐ in their paths produced in a cathode ray tube.

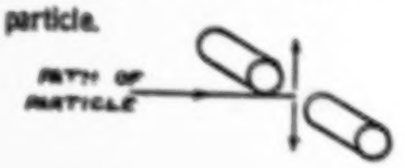
(113)

rC-3 If an object is placed in their path, cathode rays will cast a ______ on the wall of the tube which indicates that cathode rays travel in *______ ______.



D-10 The space between two electrically charged plates contains an ______ field. Likewise, the space between two magnets contains a *______.

D-24 As shown in this figure, the direction of deflection may be either ______ or ______ depending on the position of the magnets and the charge on the particle.



D-38 Because he knew the strength of the two ______ acting on the beam of electrons, Thomson was able to determine their speed, that is, their ______.

D-52 The ratio, $______, does not tell the value of either e or m, but only the ______ between them.

d-5

negative
positive

---

d-19

negative
not have been deflected (in either direction by either plate)

---

d-33

fields
B

---

d-47

mass (charge)
charge (mass)
not

rc-3

shadow
straight lines

---

d-10

electric
magnetic field

---

d-24

up (down)
down (up)

---

d-38

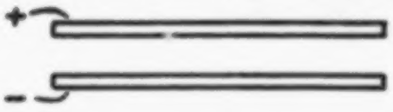
fields (forces)
velocity

---

d-52

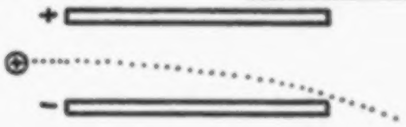
e/m
relationship (ratio)

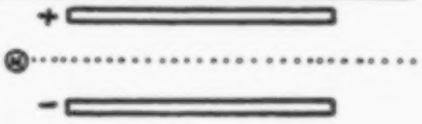
D-5 A metal plate connected to the negative terminal of a battery will have a ☐ charge and a plate connected to the positive terminal will have a ☐ charge.



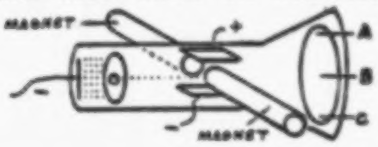
911

D-19 If electrons had a positive charge, they would have been deflected toward the ☐ plate. If they were neutral particles, they would ☐ **





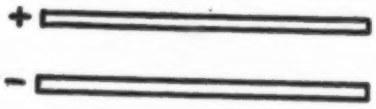
D-33 Thomson, about 1900, built a cathode ray tube containing both electric and magnetic ☐. With both fields turned off, the beam of electrons would strike the fluorescent screen at point ☐ $.



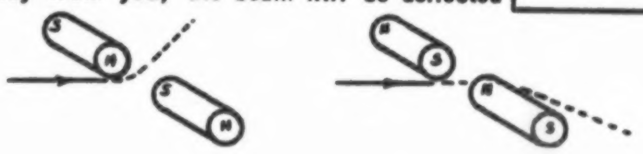
D-47 Thomson determined that the charge/mass ratio of an electron was always constant. While he could not measure either ☐ or ☐ separately, he found the ratio did ☐ vary.

rC-4 Electrons making up cathode rays were found to have both mass and velocity. Velocity means ______, and ______ means the amount of ______ in an object.

D-11 Positively charged particles passing through an ______ field will be ______ by the negative plate. Negatively charged particles will be ______ by the positive plate.



D-25 As shown in the figure, if the electrons come from the left and North is toward you, the beam will be deflected ______. If North is away from you, the beam will be deflected ______.



D-39 Thomson found that the velocity of the electrons depended on the voltage between the cathode, or negative terminal, and the anode, or ______.

D-53 Since e/m always turned out to be the same number, physicists concluded that all electrons were probably alike; each electron having exactly the same ______ and the same ______ as every other electron.

d-4

electrons

d-18

positive

negative

d-32

South (S)

magnetic

downward

d-46

ratio (relationship)

rc-4

speed
mass
matter

---

d-11

electric
attracted
attracted

---

d-25

upward
downward

---

d-39

positive terminal

---

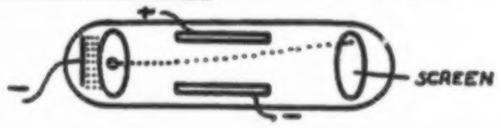
d-53

charge (mass)
mass (charge)

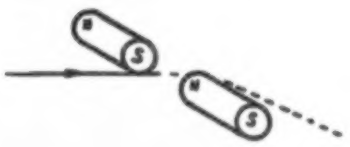
D-4 Whether or not electrons have a charge can be determined by passing a beam of ________ between two charged metal plates

---

D-18 In experiments with the tubes, it was found that cathode ray particles are deflected toward the ________ plate, indicating they have a ________ electrical charge.



D-32 In this figure, the magnet's ________ pole is toward you. In this case, the ________ field will deflect cathode rays ________.

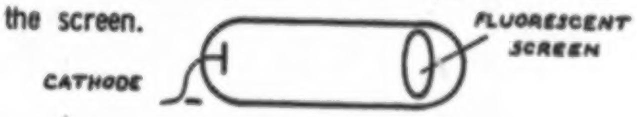


D-46 It is possible to know the ratio between two quantities without knowing the size of either. Thomson studied the ________ between the electron's charge and mass, but could not measure either separately.

rC-5 Electrons are particles consisting of matter, which means that electrons have ☐. This can be demonstrated by showing that ☐ rays can cause a pinwheel inside a tube to ☐.

(121)

D-12 To determine if electrons were charged, ☐ ray tubes were built with a fluorescent (floor-es-sent) screen at one end. The ☐ screen would glow where the cathode rays struck the screen.



D-26 If charged particles, such as cathode ray particles, move through either a magnetic field or an electric field, they will be ☐ from their original path.

D-40 The velocity of electrons is increased as the voltage between the ☐ and anode is increased.

D-54 The ratio, e/m, of an electron is always ☐ ☐. This lead physicists to conclude that all electrons have the ☐.

d-3

repelled
attracted
unlike charge

d-17

negative

d-31

they are negatively charged and they will be attracted by the + plate (and repelled by the − plate)

d-45

ratio

rc-5

mass
cathode
move

⑫③

---

d-12

cathode
fluorescent

---

d-26

deflected

---

d-40

cathode

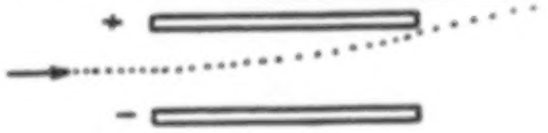
---

d-54

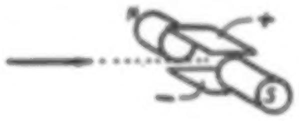
the same (constant)
same charge and the same mass

D-3 If electrons had a charge, they would be ________ by objects with a like charge, and ________ by objects with an * ________.

D-17 The cathode rays were deflected upward, being attracted by the positive plate and repelled by the negative plate. This indicated that cathode ray particles have a ________ charge.



D-31 In this diagram, the magnetic field will deflect cathode rays downward. The electric field, however, will deflect the particles upward because ** ________ ________.

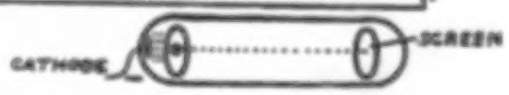


D-45 A ratio is a way of expressing a relationship. For example, mass/volume is a ________ describing the relationship of an object's mass to its volume.

rC-6 Weight is not the same as mass. By mass we mean the ____ in an object, while weight is only one way of ____ mass.

(125)

D-13 The tube had a ____ screen at one end and a metal shield with a small hole at the other end. The shield permitted only a narrow beam of electrons to go from the cathode to the ____.



D-27 An electron will be deflected as it passes through the ____ field between two magnets or as it passes through the ____ between two charged metal plates.

D-41 Thomson then measured the deflection produced by the two fields. In this way, he could measure the total amount of ____ acting on the electrons.

D-55 Since the ratio ____ is always the same, measuring the amount of charge on an electron would then make it possible to determine the ____ of an electron.

126

d-2

attract

like charges repel each other

d-16

positive (unlike, opposite)

d-30

forces

d-44

mass or size of charge

rc-6

amount of matter
measuring (determining)

127

d-13

fluorescent
fluorescent screen

d-27

magnetic
electric field

d-41

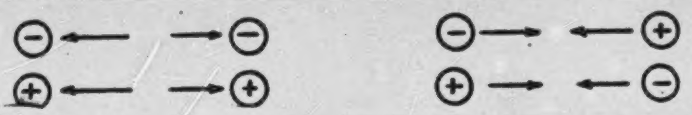
force

d-55

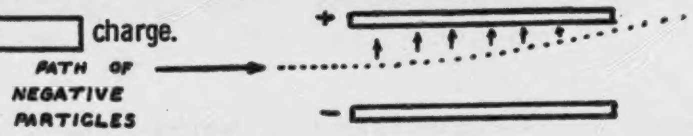
e/m
mass

128

D-2 It is possible to determine charge by using the principle that unlike charges ________ each other, while ** ________ ________.



D-16 The direction in which charged particles are deflected depends upon whether they are positively or negatively charged. Negatively charged particles would be deflected toward the plate with a ________ charge.



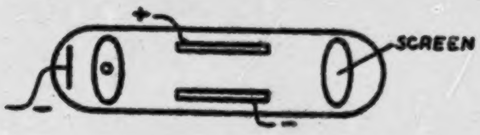
D-30 When a stream of electrons moves through both an electric field and a magnetic field at the same time, two ________ will act on the electrons

---

D-44 Thomson could not measure either the * ________ ________ on electrons directly, but he was able to study the ratio of charge/mass.

rC-7 Weight is a measure of the force of ______ between two objects due to their masses. Thus, one object by itself in space has no ______, even though it does have ______.

D-14 The tube also contained two electrically charged metal plates, one with a ______ charge and one with a ______ charge.



D-28 A beam of electrons will ordinarily travel in a ______ ______, but it will be deflected if it passes through a ______ or an ______ ______.

D-42 After measuring the velocity of electrons and their deflections, Thomson substituted these values in algebraic equations to study the mass and size of charge on an ______.

END OF UNIT

d-1

electrons
electrons
charge

d-15

field

d-29

deflected
force

d-43

mass and size of charge

rc-7

attraction
weight
mass

131

---

d-14

positive (negative)
negative (positive)

---

d-28

straight line
magnetic field (electric field)
electric field (magnetic field)

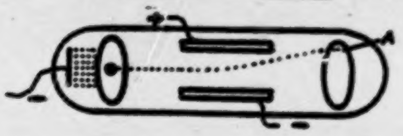
---

d-42

electron

D-1 Physicists knew that cathode rays were particles, called ________, which have both mass and velocity. Next they wanted to determine if ________ had either a positive or negative ________.

D-15 When the tube was turned on the electrons struck the screen at point A. The electrons were deflected or pulled upward as they moved through the electric ________ between the charged plates



D-29 When a beam of electrons moves through a magnetic field or an electric field, it will be ________ because the field exerts a ________ on the charged particles.

D-43 Thomson was trying to determine the mass and size of charge on the electrons. The deflections he observed depend upon both the ________ on the electrons.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER D-1

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER D-15

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER D-29

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER D-43

END OF UNIT

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UNIT E - Charge and Mass of the Electron

plus review of Unit D

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER E-4

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER E-16

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER E-28

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER E-40

END OF UNIT

rD-1 Physicists knew that cathode rays consisted of particles which have ☐. Next, they wanted to determine if these particles, called ☐, had an electrical ☐.

(137)

E-4 If the X-ray tube was off, the air between the plates would not be ☐. No ☐ would be knocked loose from the atoms of air.

E-16 In Millikan's oil drop experiment, the downward velocity of the drop depended only on its mass, but the upward ☐ depended both on its ☐ and its ☐.

E-28 Every electron has the same amount of charge. Every electron also has the same amount of ☐.

E-40 In his oil drop experiment, Millikan used X-rays to ☐ atoms in the air. Since the atoms lost electrons, they became ☐.

e-3

electrons
ions

---

e-15

number of electrons on the drop (amount of negative charge on the drop)

---

e-27

mass
small

---

e-39

ions
neutral

(139)

rd-1

mass
electrons
charge

e-4

ionized (charged)
electrons

e-16

velocity
mass (charge)
charge (mass)

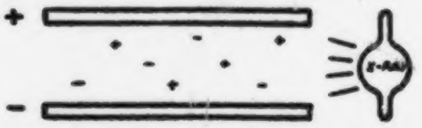
e-28

mass

e-40

ionize
positive ions

E-3 When the X-ray tube is turned on, X-rays will ionize some of the atoms in the air between the plates. Ionization means that ______ are knocked loose from atoms making them into positive ______.



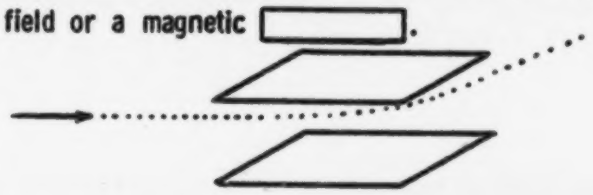
E-15 Drops with different numbers of electrons on them have different amounts of charges. In Millikan's experiment, the upward velocity of a drop depended on the ______ ______.

E-27 A trillion, trillion electrons would not even weigh as much as a speck of dust because the ______ of a single electron is very, very ______.

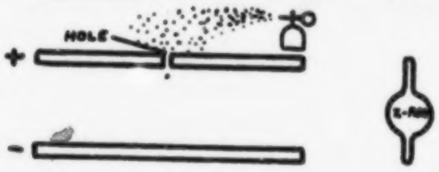
E-39 Atoms which do have a charge are called ______. An ion is an atom which is not ______.

(141)

rD-2 A beam of positively or negatively charged particles will be bent or ________ as the beam passes through either an electric field or a magnetic ________.



E-5 Millikan sprayed a light mist of oil above the + plate, and an occasional drop of ________ fell through a tiny hole in a plate.



E-17 Knowing both the upward and downward velocity of a drop, Millikan was able to compute the mass of a drop and use this value to calculate the ________ on the drop.

E-29 This series of experiments, starting with simple *________ ________ tubes, led to the discovery of the characteristics and to the precise measurement of both the **________ ________.

E-41 The atoms of any element can be ________. A positive ion of copper, for instance, is an ________ of copper that has lost some ________.

e-2

force
electric field

e-14

the amount of charge (electrical charge; negative charge; number of electrons)

e-26

mass of an electron
charge (mass)
mass (charge)

e-38

positive or negative
protons and electrons (positive and negative charges)

rd-2

deflected
field

143

---

e-5

oil

---

e-17

charge

---

e-29

cathode ray
charge and mass of the electron

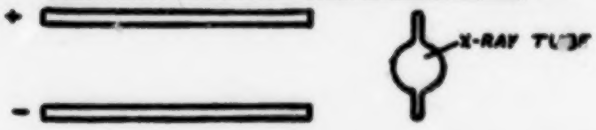
---

e-41

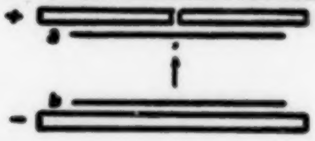
ionized
atom
electrons

(144)

E-2 Millikan's basic apparatus consisted of an X-ray tube and two charged metal plates. A ________ is exerted on charged particles passing through the ________ that exists between the plates.



E-14 When a falling drop passed line b, Millikan turned on the plates and measured the velocity of the drop as it moved upward to line a. The upward velocity depended on ________ ________ on the drop.



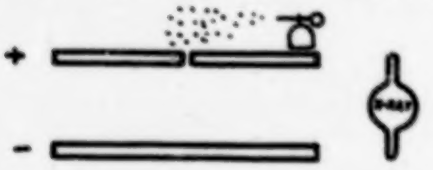
E-26 By calculating the amount of charge on a single electron, Millikan was able to determine the ________ ________. He concluded that all electrons have the same ________ and the same ________.

E-38 Ordinarily, an atom is neutral, which means it does not have either a ________ ________ electrical charge. A neutral atom has an equal number of ________.

rD-3 A beam of electrons will be deflected by magnetic fields and by ________. This would not be true if electrons did not have an electrical ________.

(145)

E-6 If the X-ray tube and charged plates were turned off, the drop of oil would fall down toward the lower plate due to the force of ________.



E-18 Millikan took hundreds of measurements on drops with different charges. He found that the amount of charge on the drops varied, as indicated by the difference between their downward and ________.

E-30 Electrons are very small ________ of matter which have a ________ charge.

E-42 Because it contains all of the protons, the nucleus of every atom has a ________ charge. If an atom loses all of its electrons, only the ________ will be left.

(146)

e-1

e/m

---

e-13

negative

upward

---

e-25

mass

the same (a constant)

---

e-37

structure

electrons

protons and neutrons (the particles)

(147)

rd-3

electric fields
charge

---

e-6

gravity

---

e-18

upward velocities

---

e-30

particles
negative

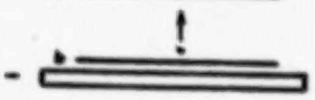
---

e-42

positive
nucleus

E-1 Millikan was the first person to measure the charge of the electron, just as Thomson was first to measure the ________ ratio of cathode rays.

E-13 Oil drops that picked up electrons will have a ________ charge. Because of their charge, when Millikan turned on the plates, these charged drops moved ________.

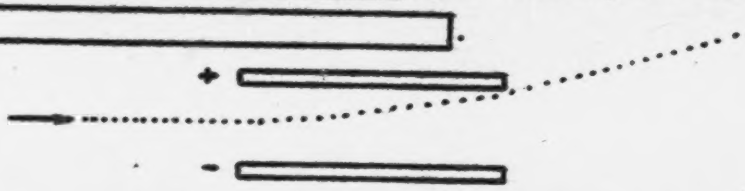


E-25 The ratio e/m is a constant. Since the charge on electrons was found to be the same for all electrons, Millikan concluded that the ________ of all electrons must also be ________.

E-37 Cathode rays were observed and studied before much was known about the ________ of an atom. Thus, physicists knew about ________ before they knew about ________ in the nucleus.

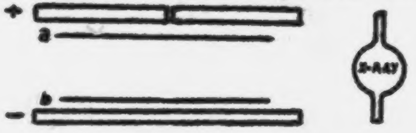
---

rD-4 A beam of electrons passing through an electric field is deflected toward the ______ plate, indicating that electrons ** ______.



(149)

E-7 As the oil drop fell from the upper to the lower plate, Millikan was able to calculate its speed, that is, its ______, by measuring how much time it took to go from line a to line b.



E-19 Every measurement of charge was evenly divisible by the smallest obtained value. That is, every larger value of charge was an even multiple of the ______ value found.

E-31 Because of their charge, electrons will be ______ by a positively charged plate and ** ______ ______.

E-43 All atoms, whether ionized or not, contain a central ______. An ion, then, is simply an ______ that has lost or gained electrons.

(150)

rd-9

alike (the same, identical)
equal (identical)

---

e-12

oil drop with fewer electrons

---

e-24

charge
mass

---

e-36

nucleus

rd-4

positive

have a negative charge

(151)

---

e-7

velocity

---

e-19

smallest

---

e-31

attracted

repelled by a negatively charged plate

---

e-43

nucleus

atom

rD-9 The e/m ratio was always constant, which suggested that electrons were all ☐, and that all electrons had ☐ amounts of charge and mass.

(152)

E-12 The forces will be greater on an oil drop that picked up many electrons than it will be on an ☐ ☐.

E-24 From his oil drop experiments, Millikan was able to calculate the ☐ on an electron. Then, by using Thomson's e/m ratio, he was able to calculate the ☐ of an electron.

E-36 The mass and charge of an electron were determined before much was known about the structure of an atom; in fact, before it was known that an atom had a central ☐.

rD-5 An electric field deflects a beam of electrons, and so will a ☐. Both fields exert a ☐ on charged particles passing through them.

(153)

E-8 When Millikan turned on the X-ray tube, X-rays knocked electrons loose from some of the atoms of air between the plates. This left the atoms of air ☐ charged.

E-20 The amount of charge on the oil drops varied in equal steps. Millikan concluded that each step or unit of charge probably represented the amount of charge on just ☐ electron.

E-32 Electrons are one of the particles that make up ☐. The electron has a ☐ electrical charge.

END OF UNIT

rd-8

the ratio between the charge and mass of the electron

154

---

e-11

amount of charge is increased

---

e-23

(amount of) charge on a single electron

---

e-35

amount of charge on an electron
mass

---

rd-5

magnetic field
force

(155)

e-8

positively

e-20

one (a single)

e-32

atoms
negative

rD-8 Although Thomson could not measure either the electron's charge or mass separately, he was able to measure e/m, which means ••____
__________.

E-11 The force of attraction or repulsion acting on the charged drops depends on their amount of charge. The force on the drops is increased as the ••______________________________.

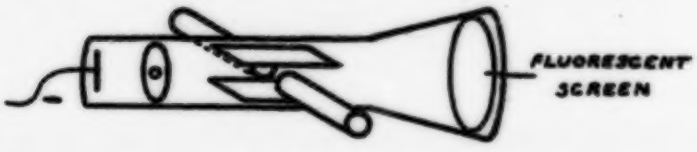
E-23 Millikan also concluded that the smallest value of charge that he observed was the ••______________________________
__________________.

E-35 Millikan, in his oil drop experiment, was able to determine the ••______________________________________.
He then could compute the ________ of an electron.

---

(157)

rD-6 To measure the deflection of electrons, Thomson built a special tube with a ________ at one end.



E-9 The falling oil drop occasionally picked up one or more of the ________ that had been knocked loose from the atoms of air. By picking up electrons, some drops thus became ________ charged.

E-33 Every electron has exactly the same amount of negative ________ and the same amount of ________ as every other electron.

E-21 The fact that Millikan found a single value that could be divided evenly into all other values suggested that all electrons have the ________ of charge.

rd-7

negative
charge (mass)
mass (charge)

---

e-10

negative
repelled
attracted

---

e-22

same amount of charge

---

e-34

e/m
the same (constant)

rd-6

fluorescent screen

---

e-9

electrons
negatively

---

e-21

same amount

---

e-33

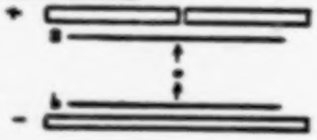
charge
mass

---

rD-7 An electron has mass, and it has a ________ electrical charge. The ratio between the ________ and the ________ of electrons was first measured by Thomson.

(091)

E-10 A drop that picked up one or more electrons would have a ________ charge. The drop would be ________ by the − plate and ________ to the + plate when the plates were turned on.



E-22 From his experiments, Millikan concluded that all electrons have exactly the * ________.

E-34 Thomson measured the $ ________ ratio of the electron. He found that the relationship between the mass and charge of an electron was always * ________.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rD-7

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER E-10

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER E-22

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER E-34

END OF UNIT

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163

UNIT F - The Mass of Atoms

plus review of Unit E

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number l. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER F-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER F-24

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER F-40

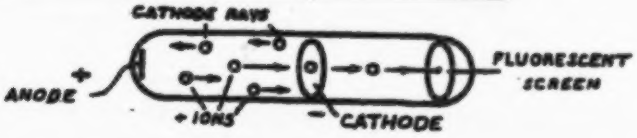
TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER F-56

END OF UNIT

START HERE

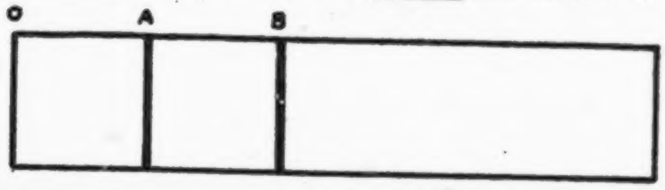
rE-1 Thomson found that e/m, the ratio between the [ ] and [ ] of an electron, was always [ ].

F-8 If the cathode in the tube is built as a disk with a small hole at its center, some positive ions will pass through the hole and strike the [*].



F-24 The ions studied in a mass spectrograph all have the same [ ] so that all the observed differences in deflection are due to differences in [ ].

F-40 If both hydrogen and helium were put in the same tube, there would be [#] lines; hydrogen at [$] and helium at [$].



F-56 Atoms with identical numbers of protons are always of the same [ ], but not all atoms of any one [ ] have the same number of neutrons.

f-7

right
opposite

f-23

differences
masses

f-39

B
A

f-55

same number of protons
different

re-1

charge (mass)
mass (charge)
constant (the same)

f-8

fluorescent screen

f-24

charge
mass

f-40

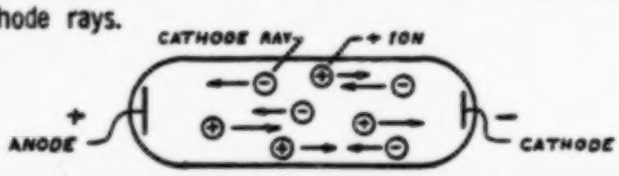
2
B
A

f-56

element
element

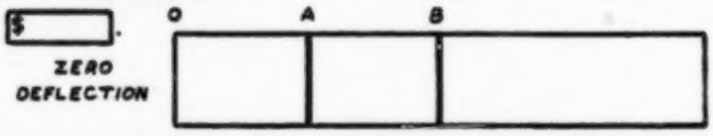
891

F-7 In the figure, cathode rays move to the left, positive ions move to the [ ]. Positive ions move in an [ ] direction from cathode rays.



F-23 For those ions having a single positive charge, differences in their amounts of deflection had to be due to [ ] in their [ ].

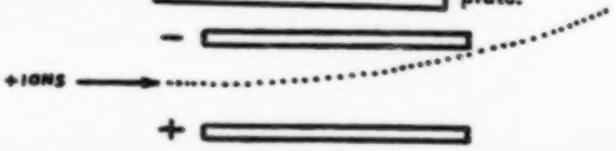
F-39 An atom of hydrogen gas has less mass than an atom of helium (hee-lee-uhm) gas. Thus, if the tube contained hydrogen, it would make a line at [$] and if it contained helium, it would make a line at [$].



F-55 Atoms of the same element always have the [**], but they may have [ ] numbers of neutrons.

rE-2 The e/m ratio was always constant, suggesting that all electrons were ________, having exactly the same ________ ________ as every other electron.

F-9 If positive ions pass through an electric field, they will be ________ from the original path. Positive ions will be deflected toward the ________ plate.



F-25 If ions that have lost only one electron are deflected by electrical and magnetic fields, the amount of deflection will depend only on their ________ since these ions all have the same ________.

F-41 By measuring where the lines appeared, Thomson found that the mass of an atom of helium was roughly 4 times the ________ of an atom of hydrogen.

F-57 Atoms of one particular element which have different numbers of neutrons are called isotopes (ice-oh-topes). Helium has two isotopes; hydrogen has three ________.

f-6

electrons
positive ion

---

f-22

same

---

f-38

less
greater the mass

---

f-54

one proton
neutrons

re-2

alike
charge and mass

---

f-9

deflected
negative

---

f-25

mass
charge

---

f-41

mass

---

f-57

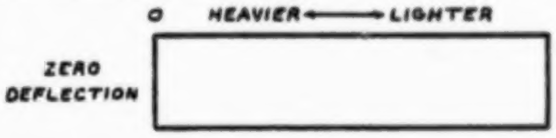
isotopes

F-6 When an electron strikes an atom of air or gas in a cathode ray tube it can knock one of the atom's ______ loose, making the gas atom into a *______.

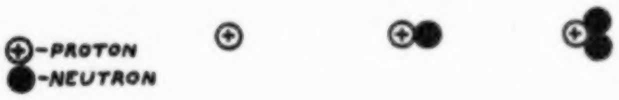
172

F-22 By properly arranging the fields, Thomson was able to study ions which had a single positive charge. All the ions studied using the mass spectrograph have the ______ amount of charge.

F-38 The greater the mass of an atom, the ______ it is deflected. Thus, the closer the line is to zero deflection, the *______ of the atom.



F-54 Three different hydrogen nuclei are illustrated. Each nucleus has only *______ but each has a different number of ______.



rE-3 Millikan, in his oil drop experiment, was able to measure the ________ on an electron by observing what happened when an electric field was switched on and off.

(173)

F-10 Positive ions will be deflected not only by an electric field, but by a *________ as well.

F-26 Using his *________, Thomson was able to determine the relative masses of ________ kinds of atoms, that is, atoms of different elements.

F-42 By noting where the lines appeared for ions of different elements, Thomson discovered that different elements produced lines at **________.

F-58 An element may have several different isotopes. The element iron, for example, has four ________ and the element oxygen has three ________.

f-5

positive
toward the negative terminal (cathode)

---

f-21

B
A

---

f-37

mass
position of the line made (place where the ion strikes)

---

f-53

proton
neutrons

---

re-3

charge

175

---

f-10

magnetic field

---

f-26

mass spectrograph

different

---

f-42

different positions (places) on the film

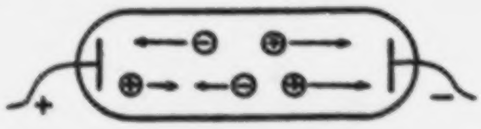
---

f-58

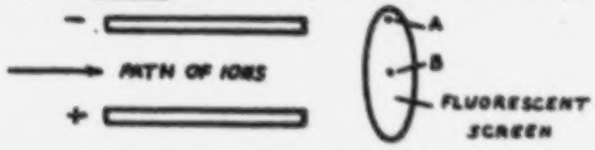
isotopes

isotopes

F-5 Electrons in a cathode ray tube move toward the [ ] terminal. Positive ions move [**] [ ].



F-21 In a mass spectrograph, a heavier positive ion will not be deflected as much as a lighter ion; thus, a heavy ion will strike the screen closer to point [$], and a lighter ion closer to point [$].



F-37 Using a mass spectrograph, the [ ] of an atom can be measured by the [**] [ ] on the film.

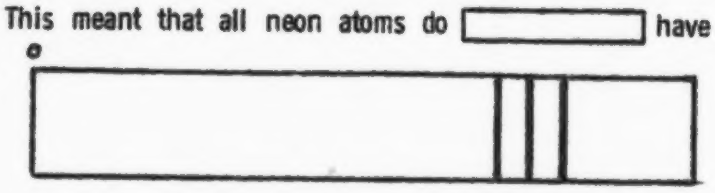
F-53 Hydrogen has an atomic number of 1. Thus, a hydrogen nucleus never has more than one [ ]. In addition, a hydrogen nucleus may also have one or sometimes two [ ].

rE-4 In Millikan's experiment, oil drops picked up ☐ knocked loose from atoms in the air. This gave the drops a ☐ charge.

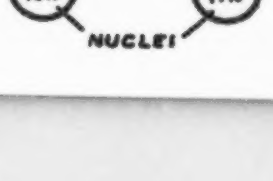
F-11 The degree of deflection of a positive ion in a combined magnetic and electric field depends both on its charge and mass. The greater the charge, the ☐ the deflection.

F-27 By observing how much ions with the ☐ amount of charge are ☐ in a mass spectrograph, it is possible to determine the relative ☐ of positive ions of different elements.

F-43 After measuring the mass of hydrogen and helium atoms, Thomson put neon gas in the tube. Instead of one line, however, he got three. This meant that all neon atoms do ☐ have the same mass.



F-59 One nucleus has 10 protons and 10 neutrons; another has 10 protons and 11 neutrons. Both are nuclei of the same ☐, neon, but they are different ☐ of that element.



f-4

negative

---

f-20

charge and mass
velocity

---

f-36

atom (ion)
position

---

f-52

protons
different
neutrons

---

re-4

electrons
negative

---

f-11

greater

---

f-27

same
deflected
masses

---

f-43

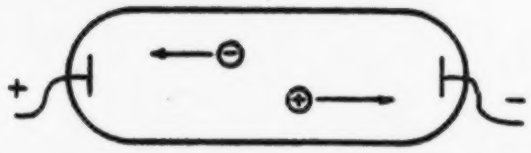
not

---

f-59

element
isotopes

F-4 A positive ion in a cathode ray tube will be attracted to the ☐ terminal.



F-20 In using a mass spectrograph all ions must travel at the same velocity. Ions cannot accurately be separated according to their ☐ unless they have equal ☐.

F-36 The position of the lines show where each kind of ☐ struck the film. The mass of an ion is indicated by the ☐ of its line.

F-52 Neon nuclei of different masses all have the same number of ☐, but each contains a ☐ number of ☐.

END OF UNIT

rE-5 The downward velocity of the oil drops in Millikan's experiment depended only on their ☐, while their upward velocity depended both on their ☐.

F-12 A given amount of force will move a pingpong ball ☐ than a bowling ball. This is because the pingpong ball has ☐ mass than the bowling ball.

F-28 A mass spectrograph is used to measure the relative ☐ of positive ions of different elements by comparing the deflection of those ions having the same amounts of ☐.

F-44 The finding that neon produced three lines was surprising since all the atoms were from the same ☐.

F-60 Atoms of the same element may have different numbers of neutrons, but they all have the same number of ☐.

f-3

atom

lost one or more electrons (negative charges)

f-19

spectrograph

mass (charge)

charge (mass)

f-35

film (screen)

mass

f-51

neutrons

f-67

isotopes

mass

re-5

mass
mass and charge

(183)

---

f-12

more (farther)
less

---

f-28

mass
charge

---

f-44

element

---

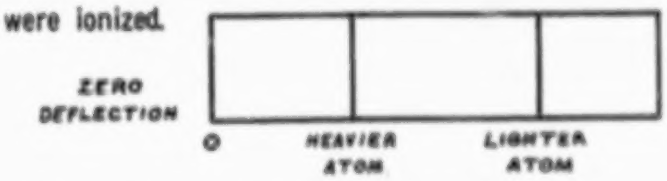
f-60

protons

F-3 A positive ion is an ______ that has ______ ______.

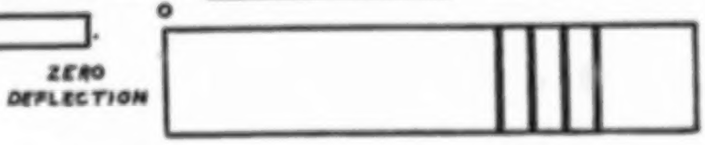
F-19 The tube which Thomson developed, called a mass ______, separated ions according to their ______ and ______.

F-35 The position of the lines on the ______ shows amount of deflection which, in turn, depends upon the ______ of the atoms that were ionized.


ZERO DEFLECTION
O
HEAVIER ATOM
LIGHTER ATOM

F-51 Since we know that all neon nuclei contain 10 protons, neon nuclei of different masses must contain different numbers of ______.

F-67 If a mass spectrograph contains ions of a single element, all with the same charge, more than one line on the film indicates that the element has several ______, each with a different ______.


O
ZERO DEFLECTION

rE-6 Since the amount of charge on an oil drop varied in equal steps, Millikan concluded that the smallest value he observed was the charge on *________.

F-13 A given amount of force will move a heavy object ________ than a lighter object. Thus, the greater the mass of a positive ion, the ________ it will be deflected.

F-29 A mass spectrograph is used to **________________________________.

F-45 Thomson discovered that there are three different types of neon atoms which have different amounts of ________. Except for the difference in mass, all neon atoms are *________.

F-61 An element consists of atoms which all have **________________________________.

f-2

positive ion

---

f-18

spectrograph

---

f-34

mass
atoms
masses

---

f-50

protons
protons

---

f-66

masses
different

re-6

a single electron

---

f-13

less

less

---

f-29

measure the relative mass of different kinds of atoms

(separate ions according to their mass)

---

f-45

mass

the same (alike)

---

f-61

the same number of protons

F-2 As electrons move through the tube they knock other electrons loose from atoms of air or gas in the tube. An atom that has lost one or more electrons is a ☐.

F-18 To test his idea, Thomson used a special tube called a mass spectrograph. In a mass ☐, ions are deflected onto a screen or photographic plate.

F-34 Physicists use a mass spectrograph to measure the ☐ of ionized atoms. Ionized ☐ of different elements have different ☐.

F-50 As you remember, the atomic number of an element indicates the number of ☐ in its nucleus. Neon, which has an atomic number of 10, has 10 ☐ in its nucleus.

F-66 The lines produced in a mass spectrograph depend on the mass of the ions striking the film. Ions of different isotopes have different ☐ and will produce lines at ☐ places.

rE-7 Millikan measured the ________ on an electron. He then determined the ________ of the electron from the $ ________ ratio.

(189)

F-14 Deflection in magnetic and electric fields will be greater for ions with the smaller amount of ________. Lighter ions will be deflected ________ than heavier ions.

F-30 A mass ________ contains some gas. If all the atoms of gas in it have the same mass, positive ions with equal charges will all be deflected an ________ amount.

F-46 To understand how atoms of the same element can differ in amount of mass, it is necessary to understand the structure of the atom. All atoms consist of a central ________ with ________ orbiting around it.

F-62 Isotopes of an ________ consist of atoms which all have the same number of protons but have ** ________ ________.

f-1

electrons (particles)
negative
positive

---

f-17

less

---

f-33

least (smallest)
D

---

f-49

nucleus
different

---

f-65

less

re-7

charge
mass
e/m

f-14

mass
more

f-30

spectrograph
equal (identical)

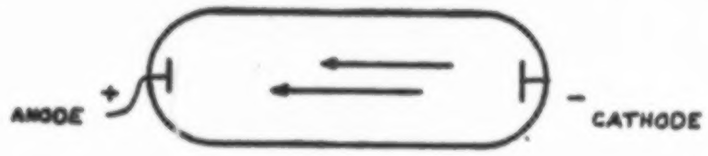
f-46

nucleus
electrons

f-62

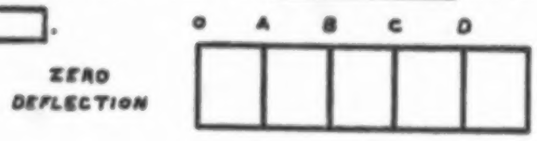
element
different numbers of neutrons

F-1 In a cathode ray tube, ________ stream from the cathode, or ________ terminal toward the ________ terminal.



F-17 Thomson reasoned that the relative masses of ions could be determined by observing their deflection in a cathode ray tube, in that heavier ions will be deflected ________ than lighter ions.

F-33 The strip of film from a modern mass spectrograph shows a line where ions struck it. On this strip, ions that were deflected most, that is, the ions with the ________ amount of mass, made a line at ________.



F-49 Almost all the mass of an atom is in the ________. Thus, atoms with different masses must have nuclei with ________ masses.

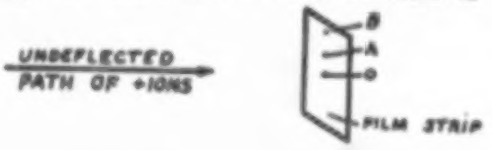
F-65 In a mass spectrograph, the greater the mass of an ion, the ________ it will be deflected.

rE-8 From his experiments, Millikan concluded that all electrons have the same ______, and each has the smallest possible ______ charge.

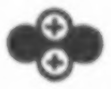
(193)

F-15 Both the mass and charge of a particle will affect the amount it is ______ in an electric or magnetic field.

F-31 A modern mass spectrograph uses a strip of film to record the deflection of ions. The mass of ions striking the film at A is ______ than the mass of ions deflected to B.



F-47 The nucleus of an atom contains positively charged particles called ______ and particles that have no charge called ______.


HELIUM
NUCLEUS

F-63 Thomson discovered the existence of isotopes by observing the deflection in the paths of positive ions as they passed through combined ______ and ______ fields in a mass ______.

re-9

negative
the smallest possible positive charge

f-16

mass and charge
mass
large (great)

f-32

off
zero (no)

f-48

proton (neutron)
neutron (proton)

f-64

less

re-8

mass
negative

f-15

deflected

f-31

greater

f-47

protons
neutrons

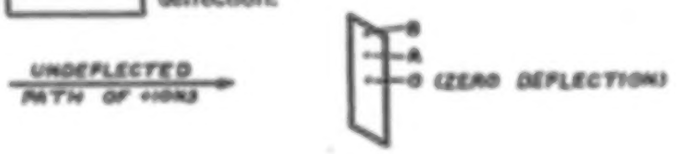
f-63

magnetic (electric)
electric (magnetic)
spectrograph

rE-9 An electron has the smallest possible ____ charge, and a proton has ** ____ ____.

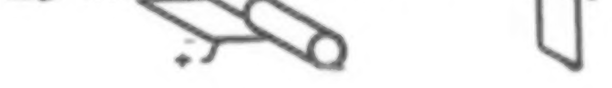
F-16 The amount an ion is deflected depends both on its * ____. Deflection will be greatest when the ion's ____ is small and when the amount of charge is ____.

F-32 In a modern mass spectrograph all ions would strike the screen at point 0, if the fields were turned ____. The "0" point indicates ____ deflection.



F-48 Protons and neutrons have about equal mass. The mass of an electron is much smaller; it would take about 1840 electrons to equal the mass of one ____ or one ____.

F-64 In a mass spectrograph, ions deflected to point A must have ____ mass than ions deflected to point B.



TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER F-9

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER F-16

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER F-32

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER F-48

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER F-64

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